Abstract

Title: Summer Microclimates and Thermal Perception in Japanese Gardens and Small Urban Parks: Hints for Climate-Adaptive Green Space Designs
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In the face of escalating global warming, the intensity and frequency of extreme weather events, including heat waves, have been increasing in various cities in Japan. This environmental context has prompted a growing demand for urban green spaces, as they have been demonstrated to offer microclimate regulation services. However, a significant barrier to climate-adaptive green space implementation lies in the limited understanding of the optimal strategies for leveraging green spaces. To fill this gap, this study was undertaken with the primary objective of exploring optimal green space designs that are adaptable to the current and projected future climates in Kyoto, Japan.

In Chapter 1, I introduce the strategic framework of this thesis, along with the presentation of key findings from existing studies and the emphatic identification of the knowledge gap. A novel facet of this thesis lies in its pursuit of climate-adaptive design strategies sourced from historical green spaces, namely Japanese gardens in Kyoto. This exploration is predicated on the hypothesis that the evolutionary trajectory of these historical gardens was intrinsically intertwined with the local climate, resulting in the provision of thermally comfortable microclimates that catered to the year-round enjoyment of the gardens. I also investigated the microclimates and thermal perception within urban parks, as we have little understanding of the current conditions of urban parks. This investigation not only seeks to comprehend the efficacy of existing urban parks in heat mitigation but also endeavors to provide recommendations for redesigning these spaces to optimally shield inhabitants from summer heat.

Chapter 2 covers the introduction of the study sites and methodology. I selected three distinct types of study sites including historic pond gardens, dry gardens, and small urban parks. Given the prevalent small size of urban parks in Kyoto, I opted to investigate historic gardens with sedentary-style characteristics that possess a small-scale design aspect. To focus on the impact of garden and park designs on individuals' thermal experiences within these sites, my investigation exclusively delved into the microclimates and thermal perceptions within the resting areas situated within the gardens and parks. Meteorological measurements were conducted during the summer period from morning to

afternoon. I used the physiological equivalent temperature (PET) to assess the thermal perception within the resting areas. Subsequently, I measured the areas of various landscape elements around the resting areas to understand their spatial configurations. Finally, I analyzed how spatial configurations affected thermal perception within the resting areas.

Chapter 3 covers the findings of the study, which focused on six resting areas in three historic pond gardens. The thermal perception within the resting areas was assessed as "slightly warm" conditions, while the nearby open areas were under "very hot" conditions. Within the pond gardens, the dominant approach for mitigating heat was demonstrated to be shade provision. The roof to pavement area ratios, which were 7:3 within a 5 m radius and 6:2 within a 10 m radius of the resting areas, played a substantial role in effectively reducing heat in the resting areas. In addition to shade provision, the large area of green ground in the pond gardens further improved thermal perception in the resting areas, whereas trees and ponds did not significantly affect the thermal perception.

Chapter 4 covers the findings of the study on nine resting areas within four dry gardens. Despite the extreme conditions observed in the garden surroundings, the resting areas exhibited significantly improved thermal perception, categorized as "warm". Similar to pond gardens, the high ratio of roofs around the resting areas ameliorated thermal perception within the resting areas from “very hot” to “warm” conditions. The ratios of the roof to the pavement in the dry gardens were 8:2 in a 5 m radius and 7:2 in a 10 m radius. This study also revealed several new insights into the association between thermal perception and surrounding spatial configurations. For example, the increase in roof area in a 20 m radius no longer improved thermal perception, whereas green ground and tree canopies improved thermal perception only in a 20 m radius from the resting areas.

Chapter 5 introduces the study of the thermal perception and design features of small urban parks. Among the 11 resting areas investigated within three urban parks, half were found to be “hot” during the noon hours. The thermal discomfort in those resting areas was due to the lack of shade. The study suggests that it is crucial to place shade elements, particularly in the west and south of the resting areas. Moreover, shade elements must be concentrated close to the resting areas. The recommended proportions for shade elements in the west and south were at least 61% and 65%, respectively. However, most resting areas did not have this condition, resulting in ineffective heat mitigation in the resting areas. Overall, the spatial design of urban parks needs to be revised to provide cool shelters for people in Kyoto.

Chapter 6 concludes the findings of Chapters 3-5 and provides climate-adaptive design strategies. The “slightly warm” and “warm” conditions in the pond and dry gardens successfully validated the hypothesis that historic green spaces can adapt to the local climate. Both pond gardens and dry gardens exhibited a common strategy of incorporating substantial shade elements around their resting areas, specifically encompassing approximately 70-80% within a 5 m radius and 60-70% within a 10 m radius from the resting areas, resulting in improved thermal comfort. Shade elements in the west and south from resting areas exhibited the most effective in heat mitigation, particularly when situated close (within 5 m) to the resting areas and covering areas exceeding 60%. Broad-ranging green coverage emerged as another pivotal heat alleviation measure, although its cooling effects were comparatively inferior to those of shade provision. Last, but not least, green spaces in the past were designed strategically in Japan, however from the investigation of thermal conditions and spatial design of urban parks, the wisdom for adapting to the local climate seems not fully embraced in the modern urban green spaces. As global warming persists, an urgent and essential task involves a comprehensive evaluation of thermal conditions in urban parks across Kyoto and other Japanese cities, coupled with the implementation of climate-adaptive design strategies to safeguard urban residents from escalating heat.